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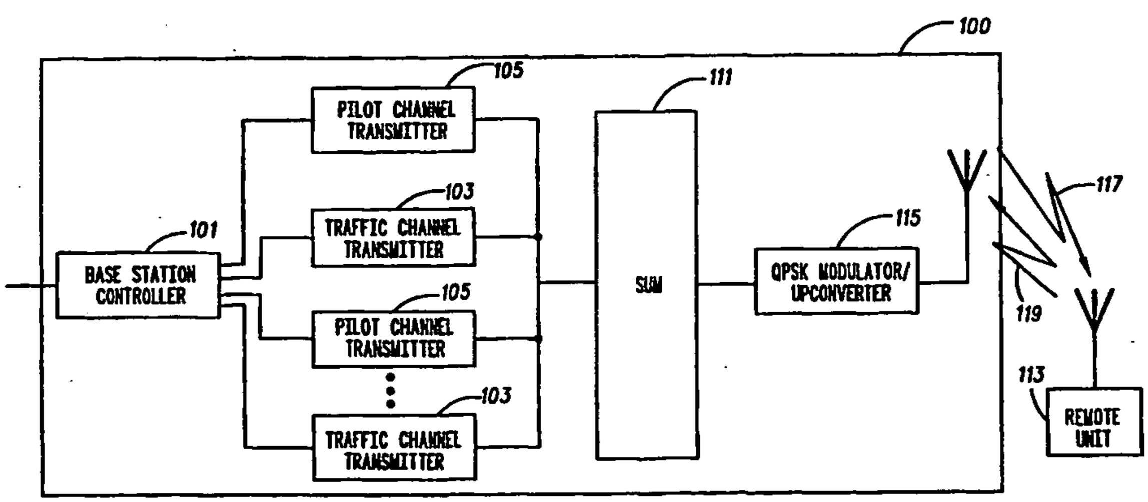

(57) Abstract

Communication within a communication system takes place utilizing both pilot channel circuitry (105) and traffic channel circuitry (103). In particular, a base station (100) utilizes traffic and pilot channels for both forward and reverse transmission. Traffic channel and pilot channel transmission from the base station (100) occurs as follows: during time periods where the remote unit (113) is actively communicating to the base station (100) utilizing a traffic channel, the remote unit (113) is actively monitoring the pilot channel for utilization in coherent demodulation of traffic channel data. In addition, the base station (100) actively monitors the speed of the remote unit (113). The base station (100) determines an appropriate transmit power based on system conditions, and optimally adjusts pilot channel transmit power based on the system conditions. In particular, pilot channel transmit power is adjusted independent of traffic channel transmit power, and is based on remote unit speed.

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ADAPTIVE POWER CONTROL OF A PILOT SUB-CHANNEL

Field of the Invention

The present invention relates generally to cellular communication systems and, in particular, to adaptive power control of a pilot sub-channel in such a communication system.

Background of the Invention

Pilot assisted modulation is commonly used for cellular communication systems. In particular, a pilot sub-channel is broadcast, providing timing and phase synchronization to aid in subsequent demodulation of a transmitted signal. Several pilot assisted modulation schemes are utilized by cellular systems. One such pilot assisted modulation scheme is a Reference Coherent type transmission as described in US Pat. No. 5,329,547, METHOD AND APPARATUS FOR COHERENT COMMUNICATION IN A SPREAD-SPECTRUM COMMUNICATION SYSTEM, by Ling, and incorporated by reference herein. As described in Ling, in a Code Division Multiple Access (CDMA) communication system, reference symbols are interspersed among the interleaved data symbols. For example, as described by Ling, a binary "1" is inserted after every three consecutive interleaved data symbols, and utilized by a receiver to help in channel estimation for coherent detection.

Another type of pilot assisted modulation occurs as proposed for utilization in the next generation CDMA communication system currently being developed, more commonly referred to as Wideband cdmaOne, or Wideband 95. Within such a communication system all remote unit and base station traffic channel transmissions have an associated pilot channel which utilizes a separate spreading code. In other words, unlike current CDMA communication systems described in Mobile Station-Base Station Compatibility Standards for Dual-Mode Wideband Spread Spectrum Cellular Systems, Telecommunications Industry Association Interim Standard 95A, Washington, DC July 1993

(IS-95A), Wideband 95 systems utilize multiple pilot channels, each associated with an individual traffic channel, to aid in demodulation.

A problem exists with the above-mentioned pilot assisted modulation schemes in that the amount of pilot power is kept constant relative to the traffic channel power. In other words, a fixed number of pilot symbols are inserted, or the power of the pilot sub-channel is kept at a constant level relative to the traffic channel power. Because of this, unnecessary interference is generated by transmission of pilot channels at an unnecessarily high power level. Therefore a need exists for adaptive power control of a pilot sub-channel that reduces system interference.

Brief Description of the Drawings

FIG. 1 is a block diagram of a base station for transmitting a pilot channel in accordance with the preferred embodiment of the present invention.

FIG. 2 is a block diagram of a pilot channel transmitter in accordance with the preferred embodiment of the present invention.

FIG. 3 is a block diagram of a speed computer of FIG. 2 in accordance with the preferred embodiment of the present invention.

FIG. 4 is a block diagram of a traffic channel transmitter for transmitting a pilot channel in accordance with an alternate embodiment of the present invention.

FIG. 5 is a flow chart showing operation of the base station of FIG. 1 in accordance with the preferred embodiment of the present invention.

FIG. 6 is a block diagram of a base station for transmitting a pilot channel in accordance with an alternate embodiment of the present invention.

Detailed Description of the Drawings

Stated generally, communication within a communication system takes place utilizing both pilot channel circuitry and traffic channel circuitry. In particular, a base station utilizes traffic and pilot channels for both forward and reverse transmission. Traffic channel and pilot channel transmission from the base station as follows: During time periods where the remote unit is actively communicating to the base station utilizing a traffic channel, the remote unit is actively monitoring the pilot channel for utilization in coherent demodulation of traffic channel data. In addition, the base station actively monitors the speed of the remote unit. The base station determines an appropriate transmit power based on system conditions, and optimally adjusts pilot channel transmit power based on the system conditions. In particular, pilot channel transmit power is adjusted independent of traffic channel transmit power, and is based on remote unit speed.

The present invention encompasses providing timing and phase synchronization in a communication system where pilot sub-channels are broadcast to aid in subsequent demodulation of a transmitted signal. A first pilot sub-channel is transmitted at a first pilot power level for utilization by a first remote unit and a first traffic channel is transmitted at a first traffic channel power level for utilization by the first remote unit. A second pilot sub-channel is transmitted for utilization by a second remote unit, at a second pilot power level and a speed is determined for the first remote unit. Finally, the first pilot sub-channel is transmitted at a third pilot power level while continuing to broadcast the first traffic channel at the first traffic channel power level, wherein the step of broadcasting at the third pilot power level is based on the determination of the speed of the first remote unit.

Another embodiment of the present invention encompasses transmitting a first pilot sub-channel at a first pilot power level for utilization by a first remote unit and transmitting a first traffic channel

at a first traffic channel power level for utilization by the first remote unit. Additionally a second pilot sub-channel is transmitted for utilization by a second remote unit, at a second pilot power level. Next, a characteristic of the first remote unit is determined and the first pilot sub-channel is transmitted at a third pilot power level while continuing to broadcast the first traffic channel at the first traffic channel power level, where the step of broadcasting at the third pilot power level is based on the determined characteristic of the first remote unit.

A final embodiment of the present invention encompasses an apparatus for adaptive power control of a pilot sub-channel comprising a first transmitter for transmitting a first traffic channel at a first traffic channel power level for utilization by a first remote unit, a second transmitter coupled to the first transmitter for transmitting a first pilot sub-channel for utilization by a second remote unit, at a first pilot power level, circuitry for determining a characteristic of the first remote unit; and a third transmitter for transmitting a second pilot sub-channel at a second pilot power level for utilization by the first remote unit, the third transmitter additionally transmitting the first pilot sub-channel at a third pilot power level, where the step of broadcasting at the third pilot power level is based on the determined characteristic of the first remote unit.

FIG. 1 is a block diagram of a base station for transmitting a pilot channel in accordance with the preferred embodiment of the present invention. The preferred embodiment of the present invention utilizes multiple pilot channels, each associated with an individual traffic channel to help aid in demodulation. Base station 100 comprises base station controller 101, multiple traffic channel transmitters 103, multiple pilot channel transmitters 105, summer 111, and modulator 115. As shown, base station 100 is communicating to remote unit 113 via downlink communication signal 117, and remote unit 113 is

communicating to base station 100 via uplink communication signal 119.

In the preferred embodiment of the present invention, communication to remote unit 113 takes place utilizing both the pilot channel circuitry 105 and traffic channel circuitry 103. In particular, base station 100 utilizes two classes of channels for both forward and reverse transmission. In the preferred embodiment, the traffic channels are similar to existing CDMA traffic channels and are used for voice and signaling. CDMA traffic channels are described in detail in IS-95A, which is incorporated by reference herein. As described in IS-95A, the transmission rate of this channel may vary dynamically. Additionally, soft hand-off (simultaneous communication utilizing more than one traffic channel circuit 103) is supported utilizing traffic channel circuitry 103. The pilot channels are utilized for assisting remote unit 113 in coherent demodulation and continuously broadcast a known pattern of 1's or 0's.

Traffic channel and pilot channel transmission from base station 100 in accordance with the preferred embodiment of the present invention occurs as follows: During time periods where remote unit 113 is actively communicating to base station 100 utilizing a traffic channel, remote unit 113 is actively monitoring the pilot channel for utilization in coherent demodulation of traffic channel data. In addition, base station 100 actively monitors the speed of remote unit 113. Base station 100 determines an appropriate transmit power based on system conditions, and optimally adjusts pilot channel transmit power based on the system conditions. In the preferred embodiment of the present invention pilot channel transmit power is adjusted independent of traffic channel transmit power, and is based on remote unit speed (however in an alternate embodiment of the present invention, pilot channel transmit power is adjusted based on feedback from remote unit 113, e.g., detection of pilot bits and adjustment of pilot power to achieve a constant target bit-error-rate). Unlike prior-art

methods of coherent demodulation where pilot sub-channel power is kept at a constant level relative to the traffic channel power, in the preferred embodiment of the present invention pilot channel power is varied relative to the traffic channel power reducing unnecessary interference.

FIG. 2 is a block diagram of a pilot channel transmitter 105 in accordance with the preferred embodiment of the present invention. Transmitter 105 includes convolutional encoder 212, interleaver 216, orthogonal encoder 220, modulator 252, upconverter 256, pilot channel gain computer (PGC) 201, speed computer 203, and antenna 258. During operation, signal 210 is received by convolutional encoder 212 at a particular bit rate (e.g., 9.6 kbit/second). Convolutional encoder 212 encodes input data bits 210 into data symbols at a fixed encoding rate with an encoding algorithm which facilitates subsequent maximum likelihood decoding of the data symbols into data bits (e.g. convolutional or block coding algorithms). For example, convolutional encoder 212 encodes input data bits 210 (received at a rate of 9.6 kbit/second) at a fixed encoding rate of one data bit to two data symbols (i.e., rate 1/3) such that convolutional encoder 212 outputs data symbols 214 at a 28.8 ksymbol/second rate.

Data symbols 214 are then input into interleaver 216. Interleaver 216 interleaves the input data symbols 214 at the symbol level. In interleaver 216, data symbols 214 are individually input into a matrix which defines a predetermined size block of data symbols 214. Data symbols 214 are input into locations within a matrix so that the matrix is filled in a column by column manner. Data symbols 214 are individually output from locations within the matrix so that the matrix is emptied in a row by row manner. Typically, the matrix is a square matrix having a number of rows equal to the number of columns, however, other matrix forms can be chosen to increase the output interleaving distance between the consecutively input non-interleaved data symbols. Interleaved data symbols 218 are output by

interleaver 216 at the same data symbol rate that they were input (e.g., 28.8 ksymbol/second). The predetermined size of the block of data symbols defined by the matrix is derived from the maximum number of data symbols which can be transmitted at a predetermined symbol rate within a predetermined length transmission block. For example, if the predetermined length of the transmission block is 20 milliseconds, then the predetermined size of the block of data symbols is 28.8 ksymbol/second times 20 milliseconds which equals 576 data symbols which defines a 18 by 32 matrix.

Interleaved data symbols 218 are input to orthogonal encoder 220. Orthogonal encoder 220 modulo 2 adds an orthogonal code (e.g., a 256-ary Walsh code) to each interleaved and scrambled data symbol 218. For example, in 256-ary orthogonal encoding, interleaved and scrambled data symbols 218 are each replaced by a 256 symbol orthogonal code or its inverse. These 256 orthogonal codes preferably correspond to Walsh codes from a 256 by 256 Hadamard matrix wherein a Walsh code is a single row or column of the matrix. Orthogonal encoder 220 repetitively outputs a Walsh code or its inverse 222 which corresponds to input data symbol 218 at a fixed symbol rate (e.g., 28.8 ksymbol/second).

PGC 201 updates pilot channel gain value Gpch 211 to minimize forward link interference while preserving adequate voice channel quality. In the preferred embodiment PGC 201 computes pilot channel gain estimate (Gpch 211) as a function of remote unit speed (supplied by speed computer) however in an alternate embodiment of the present invention Gpch 211 is calculated based on a requested power command received from remote unit 113. In particular, during low-speed, or stationary operation, pilot channel power is minimized. Additionally, in the preferred embodiment of the present invention, remote unit speed is calculated as described in US Pat: No. (Application Serial No. 08/672,703) METHOD AND APPARATUS FOR POWER CONTROL IN A COMMUNICATION SYSTEM by Love et al. Gpch 211 is then output to

multiplier 240, which multiplies Walsh code's 222 amplitude by gain value Gpch 211, resulting in a sequence of weighted Walsh codes 242. Sequence of weighted Walsh codes 242 is prepared for transmission over a communication channel by modulator 252. The spreading code is a user specific sequence of symbols or unique user code which is output at a fixed chip rate (e.g., 3.6864 Mchip/second). In addition, the user code spread encoded chips are scrambled by a pair of short pseudorandom codes (i.e. short when compared to the long code) to generate an I-channel and Q-channel code spread sequence 226. The I-channel and Q-channel code spread sequences 226 are used to bi-phase modulate a quadrature pair of sinusoids by driving the power level controls of the pair of sinusoids. The sinusoids output signals are summed, bandpass filtered, translated to an RF frequency, amplified, filtered via upconverter 256 and radiated by antenna 258 within a 5 MHz bandwidth to complete transmission of channel data bits 210.

Estimation of Remote Unit's Speed

Because there exists a relationship between the bandwidth of a faded signal received from a remote unit and a remote unit's speed, an estimation of a remote unit's speed can be determined from estimating the bandwidth of the faded signal. In a preferred embodiment, a classic fading model is used in which the mobile is driving through an infinite field of minute scatterers which results in a U-shaped power spectrum, S(f). Assuming a vertically polarized electric field:

$$S(f) = \frac{S_0}{\sqrt{1-\left(\frac{f}{f_m}\right)^2}}$$

where S_O is a constant giving the received power density within a small neighborhood of the transmit carrier frequency and f is the independent frequency variable.

The corresponding correlation function of the real part (R) of the electric field (J_o) in delay is

$$R(\nu,\tau)=J_0(\beta\nu\tau)$$

where

b = 2p/l

v = the remote unit's speed

t = the independent delay variable

and

$$f_m=\frac{\beta\nu}{2\pi}.$$

Estimating f_m will provide an estimate of v. The standard deviation with respect to f of S(f) is:

$$\sigma=\frac{f_m}{\sqrt{2}}.$$

If the carrier is at 900 MHz (a typical operating frequency for CDMA), then:

$$\hat{\nu}=1.06\sigma.$$

If frequency offset, f_0, is present, the resulting spectrum is

$$S'(f) = S(f-f_0).$$

One can approximate f_0 by estimating a mean of the two sided, generally asymmetric, spectrum. The mobile speed may be estimated by finding the second central moment (variance) of the observed power spectrum, and the frequency offset between transmitter and receiver may be obtained by estimating the first moment (mean). For example, a speed estimate is obtained by measuring the standard deviation of the remote unit's observed power spectrum. The remote unit's power spectrum is approximated by carrying out the following steps:

1) compute the complex Fast Fourier Transform (FFT) of the data selection block (described in FIG. 5).
2) form the magnitude square of the FFT
3) average several magnitude square FFT's
4) set to zero, terms in the average function which are below a threshold.

If the peak of the power spectral density (PSD) is denoted PSD_{max}, spectral values below $PSD_{max}/3.5$ are not included in the moment calculation. The threshold will, in general, be an inverse function of the signal-to-noise ratio.

FIG. 3 is a block diagram of speed computer 203 of FIG. 2. Speed computer 203 comprises RF front end 301, despreader 303, Data Selector 303, and discrete Fourier transformer (DFT) 307. Operation of speed computer 203 occurs as follows: A mixed, downconverted signal emerging from RF front end 301 enters despreader 303 where the incoming signal is despread. Pilot symbols emerge from despreader 303 and enter data selector 305 where pilot symbols are passed to DFT 307. In a preferred embodiment, the DFT design parameters are:

1. the number of input terms in the calculation of a single DFT (2 frames, 192 symbols used here).
2. the number of frequency points in the output DFT (4*192).
3. the number of DFT's averaged before computation of means and variances (5, i.e., once per 10 input frames).
4. the time constant used to filter the offset and speed estimates obtained immediately from the mean and variance.

In an alternate embodiment a power control bit stream is utilized for calculating the remote unit's speed. At the low speed, the power control bit stream exhibits periods of a regular up/down pattern that corresponds to channel coherence time. When neither signal is faded the pattern is similar to '11111000001111100000.' Thus an indication of velocity can be obtained by searching for discrete components in a frequency transform of the power control bit stream. If it is determined that much of the energy is located at a few predetermined frequency groups, the remote unit's speed is low, otherwise the remote unit's speed is high. The following steps are taken in the alternate embodiment:

1. Buffer the power-control bit stream for 2 frames (32 bits).

2. When the buffer is full, compute a 32-ary Fast Hadamard Transform of the bits, treating 0's as -1's and 1's as 1's.

3. Examine the 32 outputs. If 50% of the energy is located at 8 or fewer predetermined terms, declare the speed to be less than 10 mph; otherwise declare it to be above 10 mph.

FIG. 4 is a block diagram of a traffic channel transmitter 103 for transmitting a pilot channel in accordance with an alternate embodiment of the present invention. In the alternate embodiment of the present invention pilot transmission occurs by inserting reference symbols with the interleaved traffic-channel data symbols. Transmitter 103 includes convolutional encoder 412, interleaver 417, orthogonal encoder 420, modulator 452, upconverter 456, pilot symbol inserter 450, and gain computer 401.

During operation, signal 410 (traffic channel data), is output by a voice encoder (vocoder) and is received by convolutional encoder 412 at a particular transmission rate (e.g., 9.6 kbit/second). Input traffic channel data bits 410 typically include voice converted to data by a vocoder, pure data, or a combination of the two types of data, and is output at a particular data rate (i.e., full rate, 1/2 rate, 1/4 rate, 1/8 rate . . . etc.). Convolutional encoder 412 determines the transmission rate and encodes input data bits 410 into data symbols at a fixed encoding rate with an encoding algorithm which facilitates subsequent maximum likelihood decoding of the data symbols into data bits (e.g. convolutional or block coding algorithms). For example, convolutional encoder 412 encodes input data bits 410 (received at a rate of 9.6 kbit/second) at a fixed encoding rate of one data bit to three data symbols (i.e., rate 1/3) such that convolutional encoder 412 outputs data symbols 414 at a 28.8 ksymbol/second rate.

Data symbols 414 are then input into interleaver 417. Interleaver 417 interleaves the data symbols 414 at the symbol level. In interleaver 417, data symbols 414 are individually input into locations within a matrix so that the matrix is filled in a column by column manner.

Data symbols 414 are individually output from locations within the matrix so that the matrix is emptied in a row by row manner. Typically, the matrix is a square matrix having a number of rows equal to the number of columns; however, other matrix forms can be chosen to increase the output interleaving distance between the consecutively input non-interleaved data symbols. Interleaved data symbols 418 are output by interleaver 417 at the same data symbol rate that they were input (e.g., 28.8 ksymbol/second). The predetermined size of the block of data symbols defined by the matrix is derived from the maximum number of data symbols which can be transmitted at a predetermined symbol rate within a predetermined length transmission block.

Pilot symbols are inserted (punctured) by pilot symbol inserter 450 into the interleaved data symbol stream. In particular, a binary "1" is inserted in every Nth symbol slot. In a first alternate embodiment of the present invention N is kept constant and the magnitude of the inserted reference symbols are varied based on system conditions. In a second alternate embodiment of the present invention, the magnitude of the reference symbols are kept constant with respect to the magnitude of traffic channel symbols, however, the value of N is varied based on system conditions.

As discussed above, the receiver utilizes the pilot symbols (reference symbols) to help in channel estimation for coherent detection. In particular, in the first alternate embodiment, gain computer 401 receives a pilot channel power request (either a power-up or a power-down request) from remote unit 113, and varies the pilot channel gain value (Gpch 403) accordingly. In other words, gain computer 401, responding to a pilot channel power request from remote unit 113, adjusts Gpch 403 accordingly. Each pilot symbol is multiplied by Gpch 403 prior to symbol insertion. In the second alternate embodiment of the present invention, Gpch is kept at a constant value, and the frequency of pilot symbol insertions (N) is varied based on the pilot channel power request from remote unit 113.

In particular, in the second alternate embodiment, pilot symbols are inserted every Nth symbol slot, where N is dependent on a pilot channel power requested by remote unit 113. For example, when remote unit 113 requests a maximum pilot channel power, N is set equal to 4, and is then increased by a factor of two until an increase in pilot channel power is requested, at which point N is decreased by a factor of two.

Interleaved data symbols 418 (having pilot symbols inserted) are input to orthogonal encoder 420. For IS-95-type transmission orthogonal encoder 420 M-ary modulates the interleaved data symbols 418. For example, in 64-ary orthogonal encoding, each sequence of six interleaved data symbols 418 are replaced by a 64 symbol orthogonal code. These 64 orthogonal codes preferably correspond to Walsh codes from a 64 by 64 Hadamard matrix wherein a Walsh code is a single row or column of the matrix.

Gain computer 401 updates traffic channel gain values Gtch 444 based upon power control commands received from remote unit 113, however, in an alternate embodiment of the present invention, Gtch is adjusted based on remote unit 113 speed as discussed above in reference to FIG. 2. In the alternate embodiment of the present invention, Gtch is regulated independent of traffic channel gain Gpch. Gtch 444 is then output to multiplier 440, which multiplies Walsh code's 422 amplitude by gain value Gtch 444 resulting in a sequence of amplitude weighted and polarity modulated Walsh codes 442. A sequence of amplitude weighted and polarity modulated Walsh codes 442 is prepared for transmission over a communication channel by modulator 452. PN Generator 427 provides a spreading code which is combined with the output from multiplier 440. The I-channel and Q-channel code spread sequences 426 are used to bi-phase modulate a quadrature pair of sinusoids by driving the power level controls of the pair of sinusoids. The sinusoids output signals are summed, bandpass filtered, translated to an RF frequency, amplified, filtered via

upconverter 456 and radiated by antenna 458 to complete transmission of channel data bits 410. Because the amount of pilot power is dynamically adjusted relative to the traffic channel power, system interference is reduced.

FIG. 5 is a flow chart showing operation of the base station of FIG. 1 in accordance with the preferred embodiment of the present invention. As mentioned above, in the preferred embodiment of the present invention pilot channel power is varied with respect to traffic channel power based on a speed of remote unit 113. The logic flow begins at step 501 where remote unit 113 requests that a traffic channel be assigned to remote unit 113. Next, at step 505 base station 100 assigns remote unit 113 a traffic channel, and at step 510 a pilot channel is assigned to remote unit 113. In the preferred embodiment of the present invention, a separate pilot channel is assigned for each traffic channel assigned, and is initially set to a maximum level of 25% of the traffic channel power. It should be noted that although description of the preferred embodiment describes communication with remote unit 113 utilizing a single traffic channel and pilot channel, simultaneous communication with multiple remote units can take place utilizing multiple traffic and pilot channels each transmitted at separate power levels.

Continuing, at step 515 pilot channel transmitter 105 determines remote unit 113 speed, and at step 520, determines if remote unit 113 speed is greater than a threshold (10 Mph). If at step 520 it is determined that remote unit 113 speed is greater than 10 Mph, then the logic flow continues to step 530, otherwise the logic flow continues to step 525 where pilot channel power is set to a minimum level of 5% of traffic channel power, and the logic flow continues to step 530. At step 530 base station controller 101 determines if the traffic channel has been dropped, and if not the logic flow returns to step 515, otherwise the logic flow continues to step 535 where the traffic channel is dropped, and then to step 540 where the paging channel is dropped.

FIG. 6 is a flow chart showing operation of the base station of FIG. 1 in accordance with the alternate embodiment of the present invention. In the first alternate embodiment of the present invention, remote unit 113 actively monitors the pilot channel power and requests base station 100 to increase or decrease pilot channel power. The logic flow begins at step 601 where remote unit 113 requests that a traffic channel be assigned to remote unit 113. Next, at step 605 base station 100 assigns remote unit 113 a traffic channel, and at step 610 a pilot channel is assigned to remote unit 113. In the alternate embodiment of the present invention, pilot symbols are inserted (punctured) by pilot symbol inserter 450 into the interleaved data symbol stream. In particular, a binary "1" is inserted in every Nth symbol slot. Additionally, the pilot channel is initially set to a maximum level. As discussed above, setting the pilot channel power can occur in the alternate embodiment in one of two ways. First, the value of N can be maintained and the pilot symbol power varied with respect to traffic channel symbols, and second, the frequency of pilot channel reference symbols (N) can be varied. In the first method of pilot channel power control, the value of N is kept at 4 and the pilot symbol power is set to 100% of traffic channel power. In the second method of pilot channel power control, the value of N is set originally to 4 and the pilot symbol power (gain) is set equal to the traffic channel symbol power.

Continuing, at step 615, base station controller 101 determines if a system condition exists that requires an increase or decrease in pilot channel power. In the alternate embodiment of the present invention, the system condition is equivalent to a request by remote unit 113 that an increase or decrease in pilot channel power level occur, however in an alternate embodiment of the present invention, the system condition may alternatively be remote unit 113 speed, system interference level, or multi-path conditions. If, at step 615 base station controller 101 determines that a system condition does not exist that

requires an increase or decrease in pilot channel power, the logic flow returns to step 615, otherwise the logic flow continues to step 620. At step 620 base station controller 101 determines if the system condition requires that an increase in pilot channel power occur, and if so the logic flow continues to step 630. At step 630, base station controller 101 instructs traffic channel transmitter 105 to increase pilot channel power. In particular, one of two methods are used to increase pilot channel power. The first embodiment of the present invention keeps N constant and increase only the pilot channel symbol power level, while the traffic channel power level remains constant. In particular, at step 630, pilot channel power is increased 3 dB. In the second embodiment of the present invention, pilot channel amplitude is kept constant, but insertion frequency (N) is increased. In particular, at step 630 N is increased by a factor of two. The logic flow continues to step 635.

Continuing, if at step 620 base station controller 101 determines that the system condition does not require an increase in pilot channel power, then the logic flow continues to step 625 where pilot channel transmit power is decreased. In particular, the first embodiment of the present invention keeps N constant and decreases only the pilot channel symbol power level, while the traffic channel power level remains constant. In particular, at step 625, pilot channel power is decreased 3 dB. In the second embodiment of the present invention, pilot channel amplitude is kept constant, but puncturing frequency (N) is decreased. In particular, at step 630 N is decreased by a factor of two. The logic flow then continues to step 635 where it is determined if the call has been dropped. If at step 635 it has been determined that the call has not been dropped, the logic flow returns to step 615 otherwise the logic flow continues to step 640 where the traffic and pilot channels are dropped.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those

skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. For example, in yet a further embodiment of the present invention, both the frequency of pilot channel puncturing and the pilot channel symbol amplitude can be varied simultaneously.

What is claimed is:

Claims

1. In a communication system where pilot sub-channels are broadcast, providing timing and phase synchronization to aid in subsequent demodulation of a transmitted signal, a method for adaptive power control of a pilot sub-channel, the method comprising the steps of:

transmitting a first pilot sub-channel at a first pilot power level for utilization by a first remote unit;

transmitting a first traffic channel at a first traffic channel power level for utilization by the first remote unit;

transmitting a second pilot sub-channel for utilization by a second remote unit, at a second pilot power level, the second pilot power level differing from the first pilot power level;

determining a characteristic of the first remote unit; and

transmitting the first pilot sub-channel at a third pilot power level while continuing to broadcast the first traffic channel at the first traffic channel power level, wherein the step of broadcasting at the third pilot power level is based on the determined characteristic of the first remote unit.

2. The method of claim 1 wherein the step of transmitting the first pilot sub-channel comprises the step of inserting pilot reference symbols among traffic channel data symbols.

3. The method of claim 2 wherein the step of transmitting at the first pilot power level comprises the step of inserting pilot symbols among traffic channel data symbols at a first rate and the step of transmitting at a third pilot power level comprises the step of inserting pilot symbols among traffic channel data symbols at a second rate.

4. The method of claim 2 wherein the step of transmitting at the first pilot power level comprises the step of inserting pilot symbols among traffic channel data symbols at a first rate having a first gain value and the step of transmitting at the third pilot power level comprises the step of inserting pilot symbols among traffic channel data symbols at the first rate having a second gain value.

5. The method of claim 1 wherein the step of transmitting the first pilot sub-channel comprises the step of transmitting the first pilot sub-channel utilizing a first spreading code, and the step of transmitting the first traffic channel comprises transmitting the first traffic channel utilizing a second spreading code.

6. The method of claim 5 wherein the step of transmitting at the first pilot power level comprises the step of transmitting the first pilot sub-channel at a first gain value, and the step of transmitting at the third pilot power level comprises the step of transmitting the first pilot sub-channel at a second gain value.

7. The method of claim 1 wherein the step of determining the characteristic of the first remote unit comprises the step of determining a speed of the first remote unit.

8. The method of claim 1 wherein the step of determining the characteristic of the first remote unit comprises the step of determining if a request for a pilot channel power change was sent by the first remote unit.

9. In a communication system where pilot sub-channels are broadcast, providing timing and phase synchronization to aid in subsequent demodulation of a transmitted signal, an apparatus for

adaptive power control of a pilot sub-channel, the apparatus comprising:

a first transmitter for transmitting a first traffic channel at a first traffic channel power level for utilization by a first remote unit;

a second transmitter coupled to the first transmitter for transmitting a first pilot sub-channel for utilization by a second remote unit, at a first pilot power level;

circuitry for determining a characteristic of the first remote unit; and

a third transmitter for transmitting a second pilot sub-channel at a second pilot power level for utilization by the first remote unit, the second pilot power level differing from the first pilot power level, the third transmitter additionally transmitting the first pilot sub-channel at a third pilot power level, wherein the step of broadcasting at the third pilot power level is based on the determined characteristic of the first remote unit.

10. The apparatus of claim 9 wherein the second and third transmitters transmit the first and second pilot sub-channels by inserting pilot reference symbols among traffic channel data symbols.

11. The apparatus of claim 10 wherein the second and third transmitters insert pilot symbols among traffic channel data symbols at a first rate based on a pilot channel power.

12. The apparatus of claim 9 wherein the second and third transmitters transmit the first and second pilot sub-channels utilizing a first and second spreading code respectively.

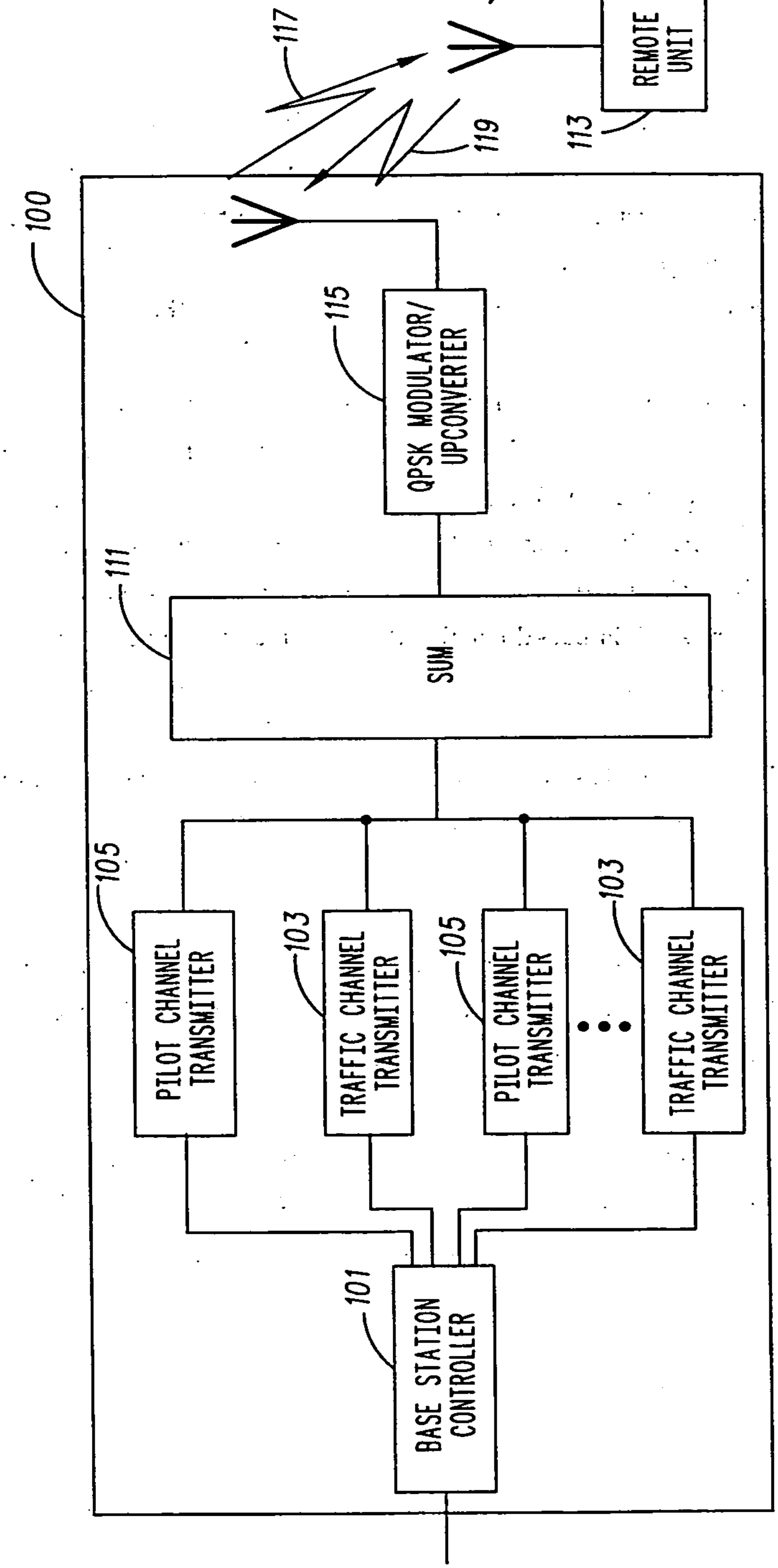
117
REMOTE UNIT
119
113
100
115
QPSK MODULATOR/ UPCONVERTER
111
SUM
105
PILOT CHANNEL TRANSMITTER
103
TRAFFIC CHANNEL TRANSMITTER
105
PILOT CHANNEL TRANSMITTER
103
TRAFFIC CHANNEL TRANSMITTER
101
BASE STATION CONTROLLER

FIG.1

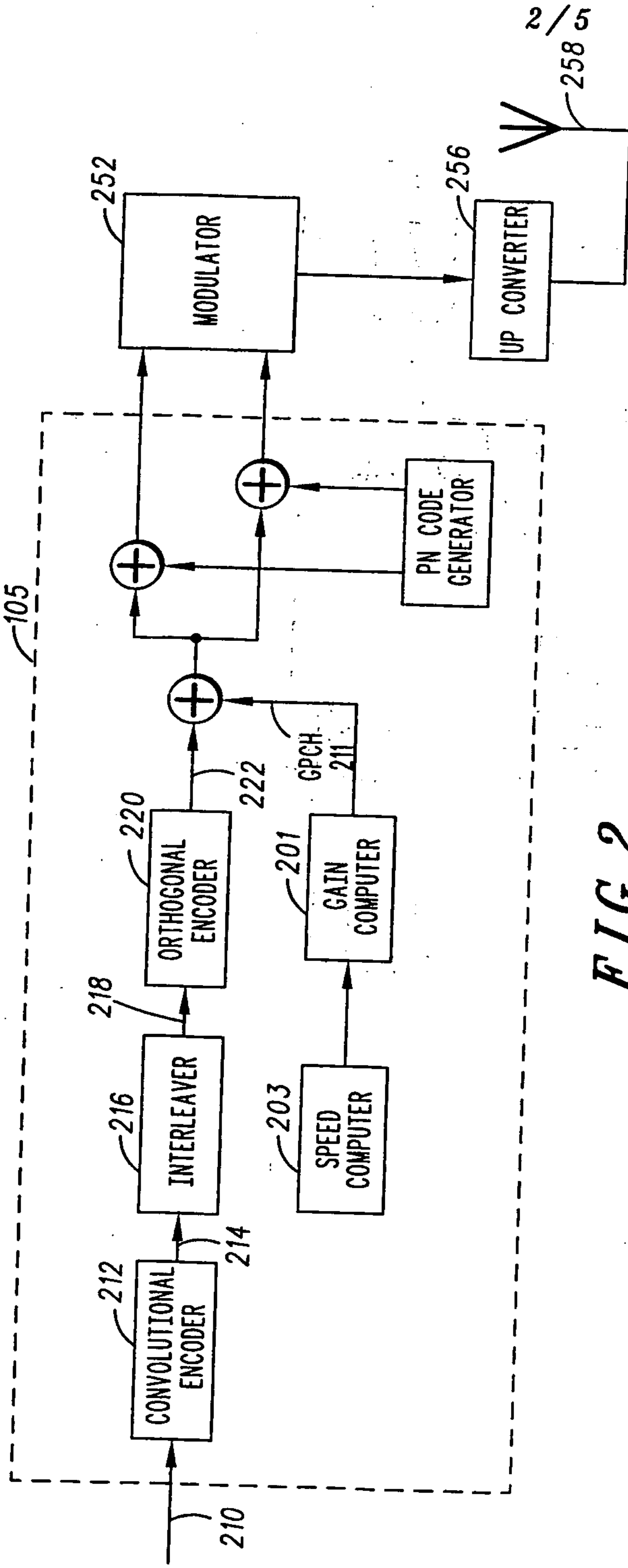
105
CONVOLUTIONAL ENCODER
212
214
INTERLEAVER
216
218
ORTHOGONAL ENCODER
220
222
SPEED COMPUTER
203
GAIN COMPUTER
201
GPCH
211
PN CODE GENERATOR
MODULATOR
252
UP CONVERTER
256
258
210

FIG. 2

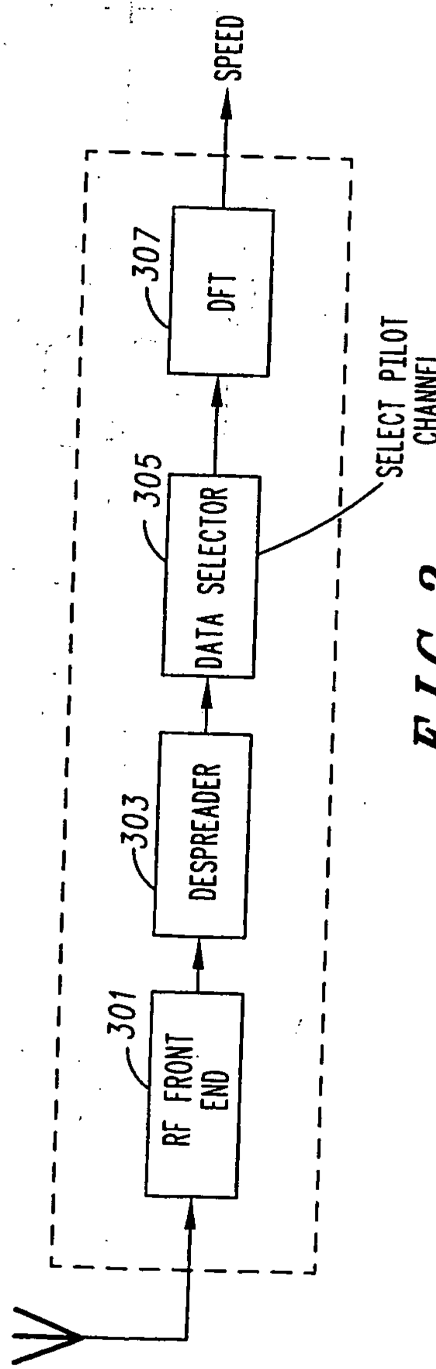
RF FRONT END
301
DESPREADER
303
DATA SELECTOR
305
SELECT PILOT CHANNEL
DFT
307
SPEED

FIG. 3

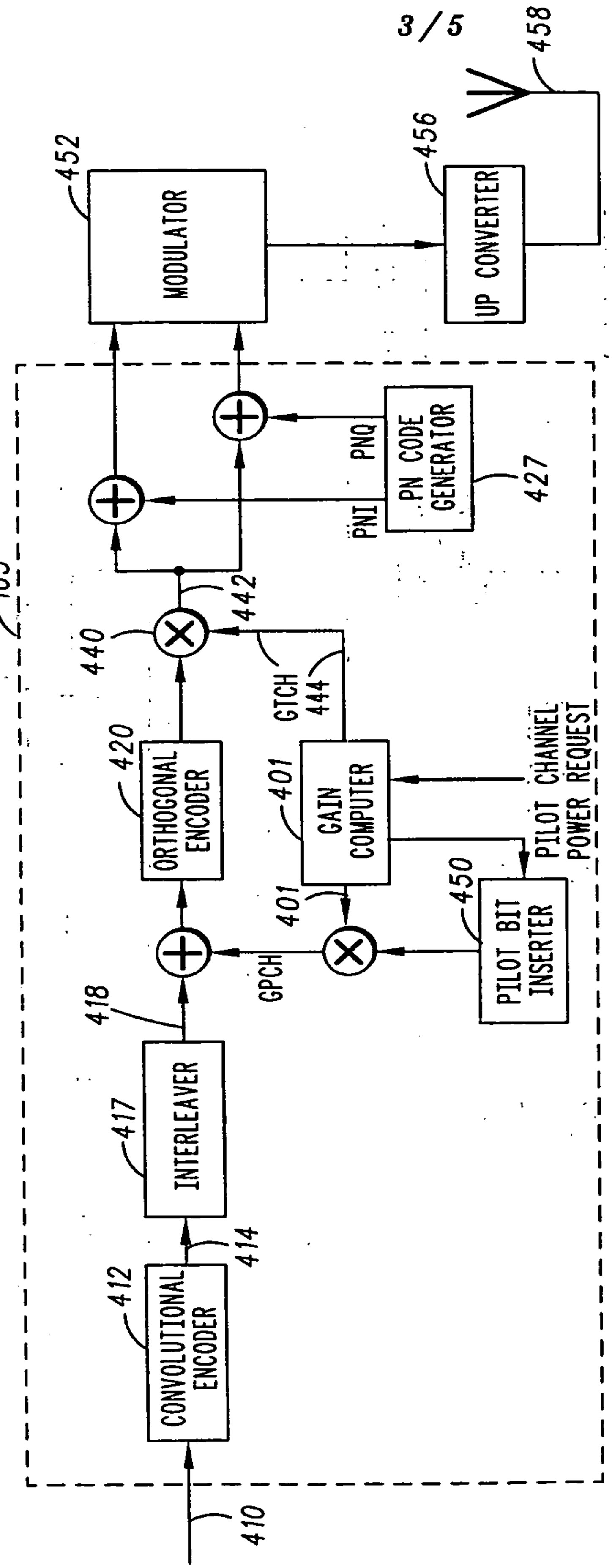
105
410
412
CONVOLUTIONAL ENCODER
414
417
INTERLEAVER
418
GPCH
401
PILOT BIT INSERTER
450
420
ORTHOGONAL ENCODER
401
GAIN COMPUTER
PILOT CHANNEL POWER REQUEST
GTCH
444
440
442
PNI
PNQ
PN CODE GENERATOR
427
452
MODULATOR
456
UP CONVERTER
458

FIG.4

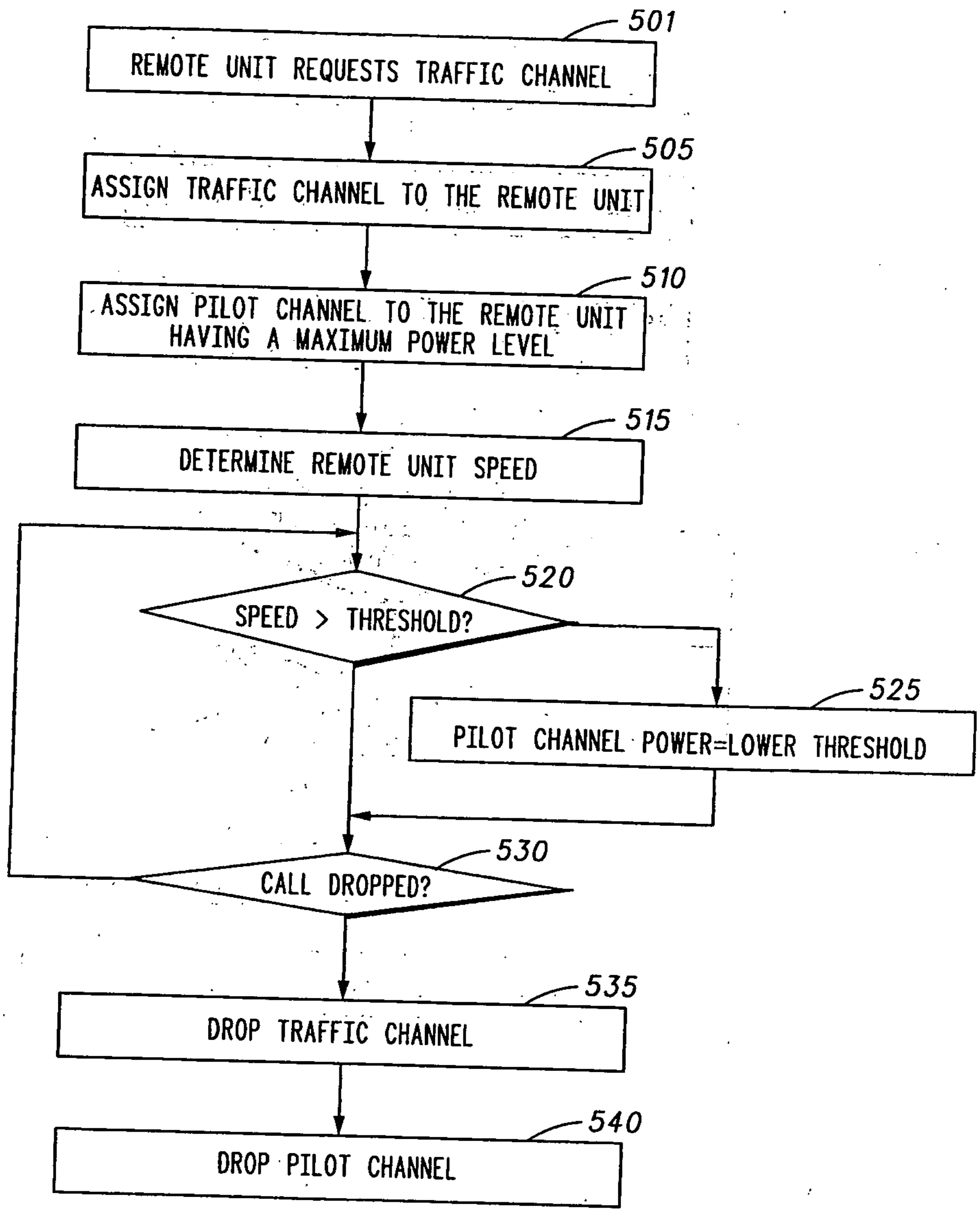
501
REMOTE UNIT REQUESTS TRAFFIC CHANNEL
505
ASSIGN TRAFFIC CHANNEL TO THE REMOTE UNIT
510
ASSIGN PILOT CHANNEL TO THE REMOTE UNIT HAVING A MAXIMUM POWER LEVEL
515
DETERMINE REMOTE UNIT SPEED
520
SPEED > THRESHOLD?
525
PILOT CHANNEL POWER=LOWER THRESHOLD
530
CALL DROPPED?
535
DROP TRAFFIC CHANNEL
540
DROP PILOT CHANNEL

FIG.5

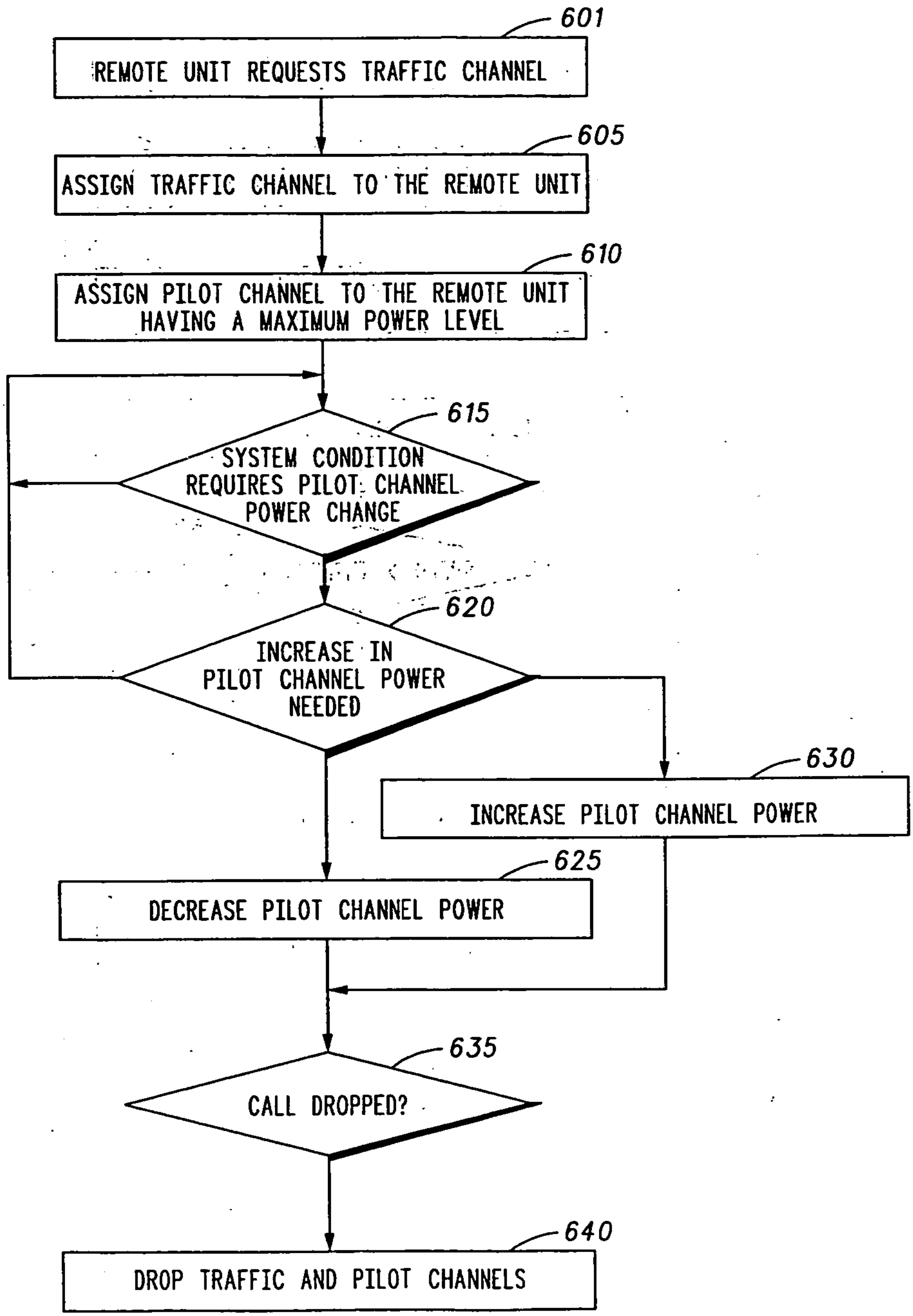
601
REMOTE UNIT REQUESTS TRAFFIC CHANNEL
605
ASSIGN TRAFFIC CHANNEL TO THE REMOTE UNIT
610
ASSIGN PILOT CHANNEL TO THE REMOTE UNIT HAVING A MAXIMUM POWER LEVEL
615
SYSTEM CONDITION REQUIRES PILOT CHANNEL POWER CHANGE
620
INCREASE IN PILOT CHANNEL POWER NEEDED
630
INCREASE PILOT CHANNEL POWER
625
DECREASE PILOT CHANNEL POWER
635
CALL DROPPED?
640
DROP TRAFFIC AND PILOT CHANNELS

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/17911

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :H04B 1/76, 3/10, 7/185
US CL :375/346; 455/522; 370/318, 491, 500
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 375/200, 346; 455/507, 517, 522, 574, 127; 370/318, 491, 500

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS search terms: pilot, power level, subchannel, speed, rate, base station, remote station, traffic channel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US 5,771,461 A (LOVE et al.) 23 June 1998 (23.06.98), Abstract, col. 2, line 13-col. 3, line 20.	1, 9
A, P	US 5,734,646 A (I et al.) 31 March 1998 (31.03.98), see its entirety.	1-12
Y	US 5,559,789 A (Nakano et al.) 24 September 1996 (24.09.96), Abstract, Fig. 4.	1, 9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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12 OCTOBER 1998

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